DEVELOPMENT OF PLUG IN DRIVE TRAIN SYSTEM FOR HYBRID ELECTRIC MOTORCYCLE

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ABSTRACT

This thesis writing discussed about the study of Development of Plug-in Drive Train System for Hybrid Electric Motorcycle. Generally, Plug-in hybrid electric vehicles (PHEVs) use batteries to power an electric motor and use another fuel, such as gasoline or diesel, to power an internal combustion engine. Beyond battery storage and motor power, parallel drivetrain configuration is used to combine the power from the electric motor and the engine, allow them to switching between the two based on the drive profile—this is called "blended mode" or "mixed mode." The major challenges in order to complete this project is to make sure drivetrain functions very well, smooth during switching between modes, thus not damaging the engine especially during blended mode. To face these challenges, it is important to develop drivetrain configuration, thus analyze its final velocity, power and torque required for each modes. A review of literature made on the hybrid drivetrain systems outlines four different modes, namely: Electric Motor (EM) mode, Internal Combustion Engine (ICE) mode, blended mode and idle mode. The configuration shows that each mode has its own functions and characteristics depends on speed demands and also needs at certain circumstances. Mechanical coupling used to connects the engine and the electric motor to the drive shafts, and before reach final drive, there will be continuous variable transmission (CVT) component, which act as main transmission instead of going through several gears to perform gear ratio change. As final outcome, drivetrain configuration that has been finalized will be used as a benchmark to develop prototype of plug-in hybrid drivetrain system, thus works well with chassis and control system.

ABSTRAK

Tesis ini membincangkan tentang Kajian Sistem Rantaian Pemacu Plug Masuk untuk Motorsikal Elektrik Hibrid. Secara am, kenderaan elektrik hibrid plug masuk menggunakan bateri sebagai sumber kuasa Elektrik Motor, dan menggunakan petrol atau diesel untuk memberi kuasa kepada Enjin Pembakaran Dalam. Selain bateri dan kuasa motor, konfigurasi rantaian pemacu selari digunakan untuk menggabungkan kuasa dari elektrik motor dan enjin, membenarkan keduanya untuk bertukar antara dua punca kuasa berdasarkan profil pandu-ini dipanggil "mod campuran". Cabaran utama dalam usaha untuk menyiapkan projek ini adalah untuk memastikan rantaian pemacu berfungsi dengan baik, lancar semasa pertukaran antara mod, sekaligus tidak merosakkan enjin terutama semasa mod campuran. Untuk menghadapi cabaran ini, ia adalah penting untuk membangunkan konfigurasi rantaian pemacu, lantas menganalisis kelajuan akhir, kuasa dan daya kilas yang diperlukan untuk setiap mod. Satu kajian sastera yang dibuat ke atas sistem rantaian pemacu hibrid menggariskan empat mod, iaitu: mod Elektrik Motor (EM), mod Enjin Pembakaran Dalam (ICE), mod campuran dan mod lelap. Konfigurasi ini menunjukkan bahawa setiap mod mempunyai fungsi tersendiri dan ciri-ciri yang bergantung kepada permintaan kelajuan serta keperluan yang bergantung kepada keadaan tertentu. Gandingan mekanikal digunakan untuk menghubungkan enjin dan motor elektrik untuk aci pemacu, dan sebelum mencapai memandu akhir, akan ada komponen Penghantar Boleh Ubah Berterusan (CVT), yang bertindak sebagai penghantar utama, sebagai ganti melalui beberapa gear untuk melaksanakan nisbah perubahan gear. Sebagai hasil akhir, konfigurasi rantaian pemacu yang telah dimuktamadkan akan digunakan sebagai penanda aras untuk membangunkan prototaip sistem plug masuk rantaian pemacu hibrid, sekaligus, berfungsi dengan baik bersama casis dan sistem kawalan.

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LIST OF SYMBOLS

Symbols

P_{air}	Air drag
C_d	Air drag coefficient
P_c	Caloric value of gasoline
S	Displacement
e	Energy
F	Force
A_f	Frontal area
d_{gas}	Gasoline line flow
g	Gravitational acceleration
L	Inductance
m	Mass
J	Moment of inertia
P_{grad}	Power demand for gradient
P_{mot}	Power motor
r	Radius
m_{ice}	Ratio of fuel into the engine
R	Resistance
P_r	Rolling resistance
C_r	Tire rolling coefficient
W	Work

Greek Symbols

ζ	Air density
θ	Angular displacement
ω	Angular velocity
ρ	Density
η_{mech}	Mechanical efficiency
Ω	Rotational speed
τ	Torque

LIST OF ABBREVIATIONS

CAD	Computer Aided Drawing
CVT	Continuous Variable Transmission
EM	Electric Motor
EREV	Extended Range Electric Vehicles
ESS	Energy Storage System
EV	Electric Vehicle
GHG	Greenhouse Gas
HV	Hybrid Vehicle
ICE	Internal Combustion Engine
PHEM	Plug-in Hybrid Electric Motorcycle
PHEV	Plug-in Hybrid Electric Vehicle
ReEV	Range-extended Electric Vehicles
SOC	State of Charge
3D	Three Dimensional
UMP	University Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

In recent years, a significant interest in plug-in hybrid electric vehicles (PHEVs) has arisen gradually due to the pressing environmental concerns and increasing price of oil. Representing a revolutionary change in vehicle design around the globe, hybrid vehicles (HV) surfaced in many different ways. However, they share the hybrid powertrain that combines multiple power sources of different nature, including conventional internal combustion engines (ICE), batteries and electric motor (EM). These vehicles with onboard energy storage devices and electric drives allows braking power to be recovered and ensures the ICE to operate only in the most efficient mode, thus improving fuel economy and reducing pollutants.

Plug-in hybrid electric vehicles (PHEVs) are sometimes called range-extended electric vehicles (ReEVs) or extended range electric vehicles (EREVs), in the sense that these vehicles always have onboard gasoline or diesel that can be used to drive the vehicle for an extended distance when the onboard battery energy is depleted. Furthermore, these vehicles can provide high fuel economy during the extended driving range due to the large battery pack that can accept more regenerative braking energy and provide more flexibility for engine optimization during the extended driving range.

PHEVs have the potential to displace transportation fuel consumption by using grid electricity to drive the car. PHEVs also can be driven initially using electric energy stored in the onboard battery, and an onboard gasoline engine can extend the driving range. Plus, PHEVs can produce significant environmental and economic benefits for society. The advantages of PHEVs can be evaluated by how much fuel is displaced, as well as by how much pollution, including greenhouse gas (GHG) emissions, can be reduced (Chris Mi et al., 2011).

Lastly, drivetrain system in vehicle serves one purpose, which is to transfer engine power to the ground. Its configuration is designed according to various kinds of driving conditions and the choices of wheels to be powered by the engine or driven. Transmission and final drive components work together to make this happen. The transmission takes the output from engine and manipulates it to control speed, direction, and torque. The final drives reduce speed and increase torque.

1.2 PROBLEM STATEMENTS

Drivetrain is very important in vehicle design; this is due to its function to helps control the speed and power through gears. It also functions to transfer power from the engine to the wheels in order to propel the vehicle. Due to these purposes, it is important to determine the drivetrain efficiency before developing new drivetrain system especially in PHEV Motorcycle because it involves more drivetrain mechanism.

The vehicle engine supplies power through the combustion process. This process drives the flywheel positioned at the engine rear. The flywheel connects to the vehicle transmission system in order to adjust the power to the wheels for different applications. It also determines the power to be distributed to the other components in the drivetrain. In Hybrid System, power from two sources of drivetrain is combined which is from ICE and also EM. Thus, it is compulsory to provide proper power required so that the ICE did not damaging the EM, and vice versa. In addition, final velocity of final drive for both ICE and EM can be recorded.

Because of this, it is important to make sure that the drivetrain functions very well with other component mechanisms, such as control module. The change of mode for the drivetrain must as smooth as possible in order to reduce loss. In behalf of this, it is necessary to make a drivetrain system with a proper distribution of power from both power sources, so that it switch mode in a proper way, not damaging the engine especially during blended mode, thus, works well with other mechanisms in Plug-in Hybrid Electric Motorcycle that are going to be develop.

1.3 OBJECTIVES

a. To develop drivetrain system for plug-in hybrid electric motorcycle proper configuration.
b. To analyze proper power and torque required of drivetrain.

1.4 SCOPES OF STUDY

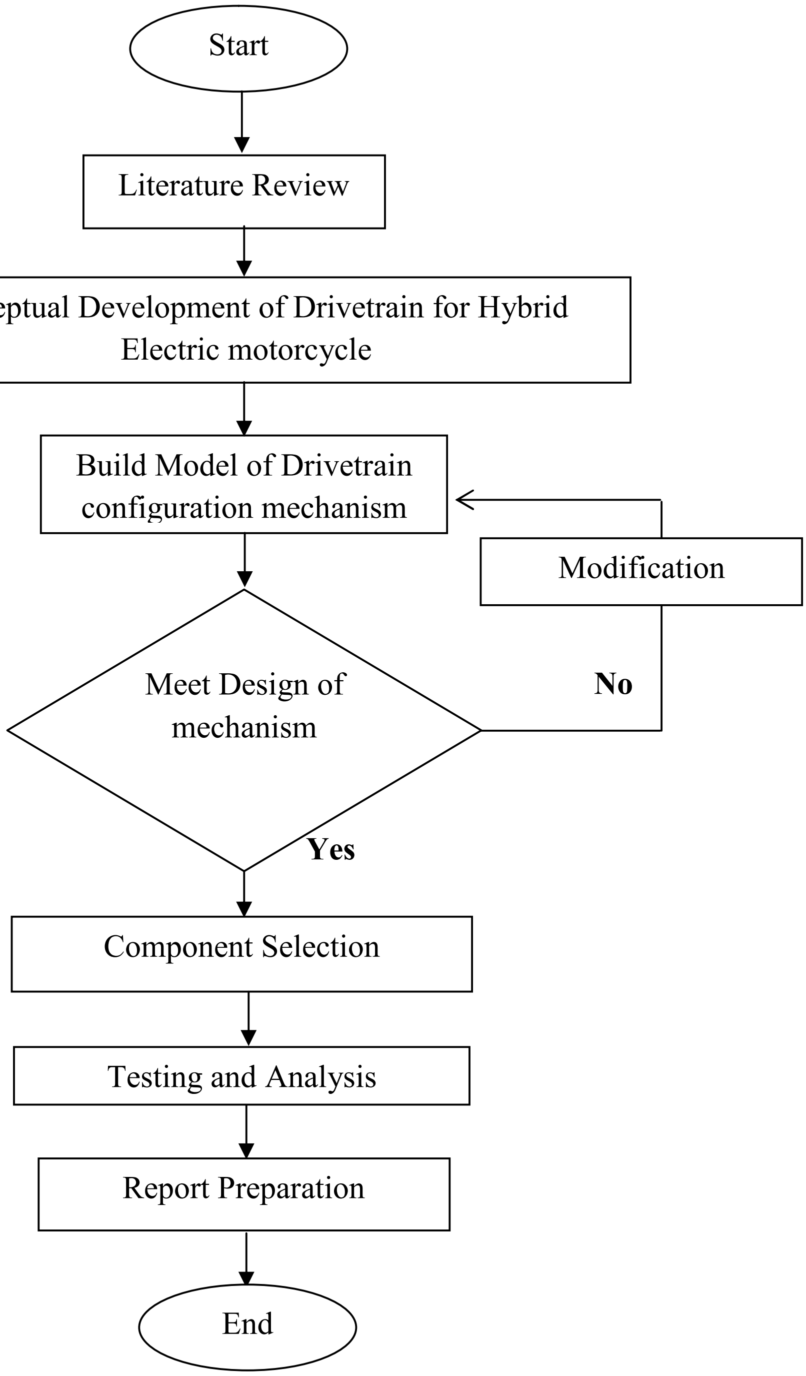
The scopes for this project are as following:

a. Conceptual Development Of Drivetrain For Hybrid Electric motorcycle
b. Benchmarking and component selection for Plug-In Hybrid Electric Motorcycle Drivetrain.
c. Development of model for Hybrid Electric Motorcycle drivetrain configuration. .
d. Experiment configuration analysis and data collection.
e. Final report preparation.

1.5 HYPOTHESIS

Drivetrain served as one of very important mechanisms in Plug-In Hybrid Engine Motorcycle development, which consist of engine, clutch, transmission, driveshaft, differential, axles and wheels. By the end of progress development, all of the component of drivetrain must be assemble; functioning well with no problem to switch between modes, having proper power distribution which means did not damaging power sources, thus works well with other mechanism in order to make sure the prototype model is successful.

1.6 FLOW CHART



1.7 GANTT CHART

The Gantt chart is referred to Appendix A

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORICAL DEVELOPMENT OF DRIVETRAIN

The history of drivetrain systems is closely linked to the history of the vehicle. Major changes in vehicle system have often been initiated or accompanied by advances in drivetrain systems.

Getting power from the engine to the wheels of an automobile has provided a seemingly endless challenge for rear-wheel-drive, front-wheel-drive, 4-wheel-drive, front-engine, rear-engine, and mid-engine cars, longitudinal, transverse, vertical, slant, and flat engines, plus an amazing array of hardware in between. George Selden's notorious 1877 patent was for a front-drive carriage with a transverse 3-cylinder engine, anticipating the Chevy/Suzuki Sprint by over a century. When it comes to car designs, there are very few new ideas, just progressively successful adaptations of old concepts (John Barach, 2011).

The heart of the drivetrain is the transmission. Because gasoline engines develop their torque over a very narrow speed range, several gears are needed to reach useful road speeds. (Steam engines and electric motors can be used in cars with no transmissions). Table 2.1 below shows timeline of transmission development progress (John Barach, 2011).

Table 2.1: Manual Drivetrain Timeline

Year	Inventor/Innovator	Description
1877	George Selden	Front-drive carriage with a transverse 3-cylinder engine
1894	Louis-Rene Panhard and Emile Levassor	Multi-geared transmission theory (engine problem during demo)
1895	Louis-Rene Panhard and Emile Levassor	Vertically mounted engine in the front of the vehicle that drove the rear wheels through a clutch, 3-speed sliding gear transmission and chain-driven axle
1898	Louis Renault	-Connected a vertical engine with transmission to a "live" rear axle by means of a metal shaft. -Additional • Rear axle • Driveshaft Compared to Panhard, Levassor (1895)
1908	T Ford	Planetary transmission; it had a central gear, called the "sun" gear, surrounded by three "planet" gears
1928	Cadillac	Synchromesh transmissions • Synchronizing system that permits drive and driven gears to be brought into mesh with each other smoothly without gear clashing. • This system allows both sets of gears to reach the same speed before they are engaged •
1930	Walter Wilson	Wilson Preselector • Four individual planetary gear sets, allowed the driver to preselect one gear ratio by moving a small lever on the steering column

Source: John Barach, (2012).

Table 2.2: Automatic Drivetrain Timeline

Year	Inventor/Innovator	Description
1904	Sturtevant brothers	Two forward speeds that were engaged and disengaged by the action of centrifugal weights without need for a foot-operated clutch
1934	Reo	Reo Self-Shifter; two transmissions connected in series • The first transmission much the same idea used by the Sturtevants • The second transmission was shifted manually and was used only when a lower gear was needed •
1937	Oldsmobile	Four-speed semi-automatic transmission called the "Automatic Safety Transmission" (AST)
1938	Buick	Five-speed semi-automatic transmission in the Special, but it was so prone to trouble that it was dropped the following year.
1939	Oldsmobile	GM Hydra-Matic transmission • three planetary gearsets that were operated hydraulically • A fluid coupling was used to connect the engine and transmission •
1941	Chrysler	Chrysler Fluid Drive transmission • A fluid coupling was used to connect the engine and transmission • Perfecting the fluid coupling •
1948	Buick	-Evolved automatic transmission into the hydraulic torque converter (today coupled to a planetary geartrain) - known as Dynaflow fully automatic transmission
1980	Fuji heavy industries Owned by Subaru	Continuously variable transmission, or CVT, • The transmission (or the driver) shifts gears to provide the most appropriate ratio for a given situation: Lowest gears for starting out, middle gears for acceleration and passing, and higher gears for fuel-efficient cruising.

Source: John Barach, (2012).

2.2 PLUG-IN HYBRID ELECTRIC VEHICLES (PHEVs)

Plug-in hybrid electric vehicles (PHEVs) had been growing interest among researchers due to its potential to reduced operating costs, oil displacement, national security, and environmental benefits. PHEVs might be cost more to purchase compared to ICE and HEVs in term of battery costing, but for long term, this technology will benefit consumers due to its long term savings potential (Oak Ridge National Laboratory, 2010).

Table 2.3: Comparison between Hybrid Electric Vehicle and Plug-In Hybrid Vehicle.

PHEVs	HEVs
Infrastructure: • Home recharging will be a prerequisite for most consumers; public recharge infrastructure may be relatively unimportant, at least to ensure adequate driving range, though some consumers may place a high value on daytime recharge opportunities.	**Infrastructure**: • Greater need for public infrastructure to increase daily driving range; quick recharge for longer trips and short stops; such infrastructure is likely to be sparse in early years and will need to be carefully coordinated.
Economies of scale: • Mass production levels needed to achieve economies of scale may be lower than those needed for EVs, for example if the same model is already mass-marketed as a non-PHEV hybrid; however, high-volume battery production (across models) will be needed.	**Economies of scale**: • Mass production level of 50 000 to 100 000 vehicles per year, per model will be needed to achieve reasonable scale economies; possibly higher for batteries (though similar batteries will likely serve more than one model).
Vehicle range: • PHEV optimal battery capacity (and range on grid-derived electricity) may vary by market and consumer group. Willingness to pay for additional batteries (and additional range) will be a key determinant.	**Vehicle range**: • Minimum necessary range may vary by region – possibly significantly lower in Europe and Japan than in North America, given lower average daily driving levels. 100 km (62 miles) to 150 km (93 miles) may be a typical target range in the near term.

Source: Peter Taylor et al. (2011).

On the other hand, Journal Technology Roadmap; Electric and Plug-In Hybrid Electric Vehicles (Peter Taylor et al., 2011) states that PHEVs retain the entire ICE system, but add battery capacity to enable the extended operation of the EM. PHEVs have an advantage of being less dependent on recharging infrastructure and possibly less expensive (depending on battery costs and range) than EVs.

2.3 DRIVETRAIN

The drivetrain of a vehicle is composed of the components that are responsible for transferring power to the drive wheels of your vehicle. Propulsion energy of an HEV comes generally from two types of sources; one of them must be an electric source.

In addition, integrating an EM with an ICE is the most practical means of realizing an HEV arrangment, before the pure EV eventually becomes commercial. Based on different combinations of electric and mechanical traction, HEV drivetrains are divided into three basic arrangements (Chirag Desai, 2010):

a. Series hybrid
b. Parallel drivetrain
c. Power-split or series-parallel hybrid.

2.3.1 Series Drivetrain.

A series HEV typically consists of an ICE directly coupled to an electric generator. The electric motor provides all the propulsion power. The configuration of a series HEV is shown in Figure 2.1 (Chirag Desai, 2010).

In a series HEV, because of no mechanical connection between the ICE and drive wheels, it is possible to operate the ICE very close to maximum efficiency. The ICE works in its optimal operation range as an on-board generator, maintaining battery state of charge (SOC) (G. Maggetto and J. Van Mierlo, 2005).

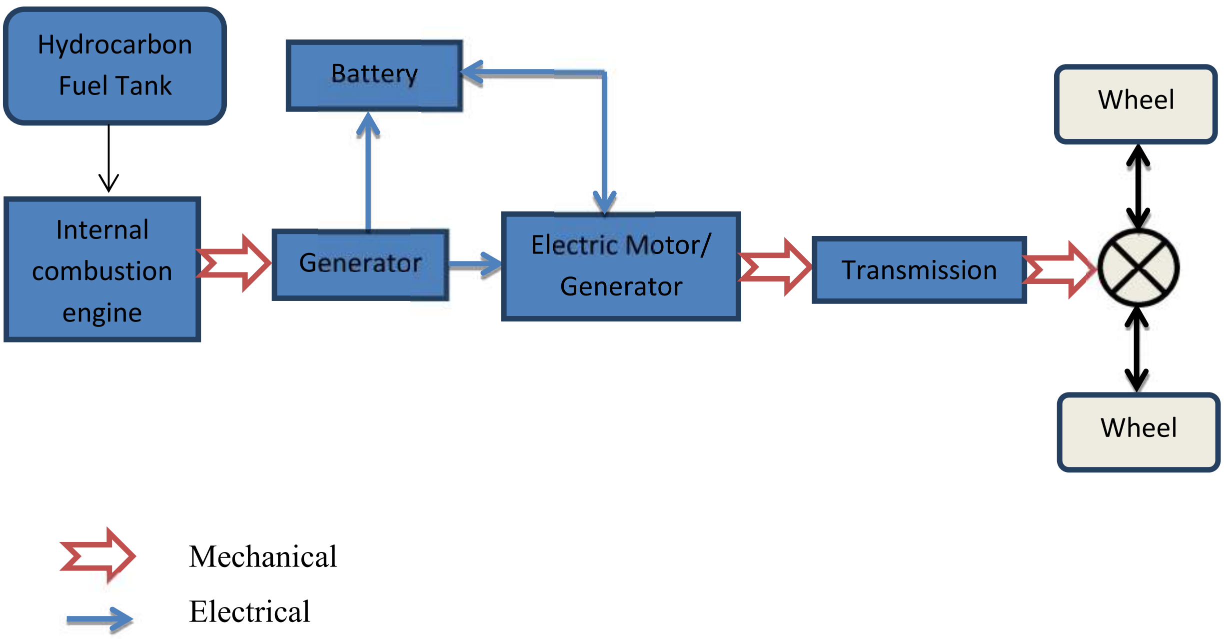


Figure 2.1: Series Drivetrain

Source: Chirag Desai, (2010)

2.3.2 Parallel drivetrain

In a parallel HEV, both the ICE and the electric motor deliver power to the wheels. A parallel HEV configuration offers freedom to choose a combination of traction sources. By merging the two different traction sources, a relatively smaller, more efficient ICE can be used. The configuration of a parallel HEV is shown in Figure 2.2 (Chirag Desai, 2010).

Since both the ICE and the EM directly supply torques to the driven wheels, no energy conversion occurs. Thus, the energy loss is low, which increases overall drivetrain efficiency. Moreover, the parallel HEV drivetrain is compact, due to the absence of an electric generator. The small size of Energy Storage System (ESS) and EM also makes the parallel HEV an attractive option. However, the control of parallel HEV drivetrain is more complicated than a series HEV (Chirag Desai, 2010).

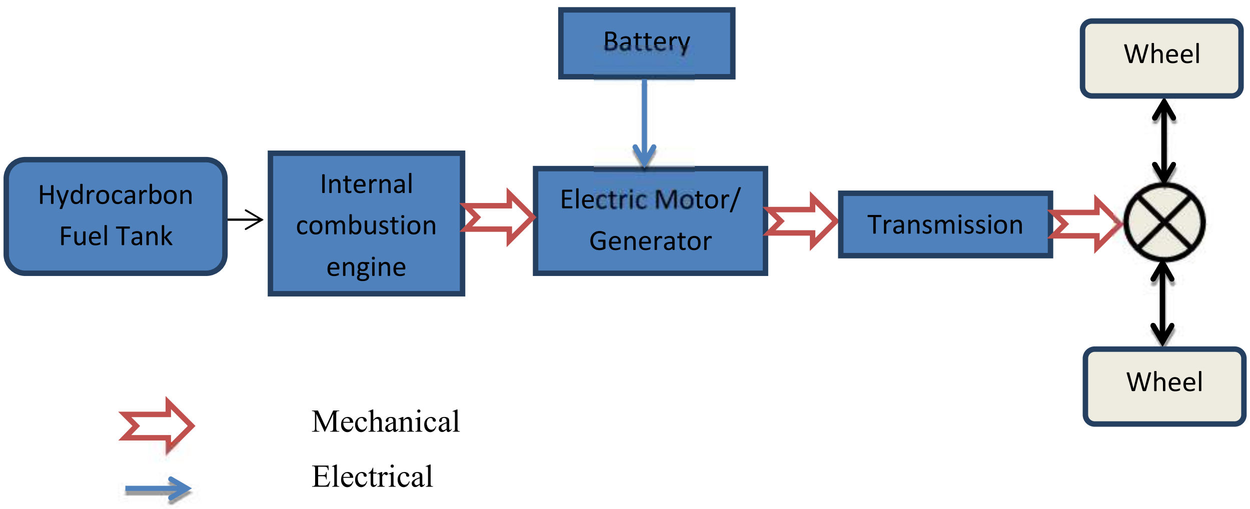


Figure 2.2: Parallel Drivetrain

Source: Chirag Desai, (2010)